Raytheon

Air Traffic Management System Development and Integration (ATMSDI)

CTO-02 – Human Factors Support for DAG-TM

CTOD 2.1-2 – FY02 Research Plans for Subtasks 1–7

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Prepared for

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1. INTRODUCTION

NASA's Distributed Air/Ground Traffic Management (DAG-TM) concept elements (CEs) envision increased operational flexibility, efficiency, safety, and capacity enabled by decision support tools (DSTs) that promote collaborative decision making and distributed, cooperative problem solving among pilots, air traffic service providers (ATSPs), and airline dispatchers. Defining characteristics of DAG-TM CEs include the redistribution of roles and responsibilities for maneuvering and separation assurance from the ATSPs to the flight deck (FD) in the en route (CEs 5, and 6) and terminal environments (CE 11).

The DAG-TM concept elements offer potential solutions to the need for increased National Airspace System (NAS) capacity, efficiency, and flexibility without a reduction in level of safety. These en route and terminal concept elements will impact the way that ATSPs, pilots, and dispatchers in airline operations centers (AOC) interact to deliver safe and efficient NAS services. This evolving distributed, cooperative problem solving environment will also affect stakeholder information needs and change “traditional” roles and responsibilities.

Fundamental human factors issues center on a redistribution of workload and the need for shared situation awareness to foster safe and effective communication and coordination. Evaluations must therefore consider all principal parties involved in DAG-TM—pilots, ATSPs, and AOC dispatchers. A cross-cutting issue that must be addressed is the responsibilities, tasks, and interactions among the aircrew (pilot flying and pilot not flying), the ATSPs, and the airline dispatchers. The different user tasks in these operational environments—en route (CEs 5 and 6) and terminal (CE 11)—will likely influence these interactions and the resultant feasibility and benefits of associated concepts and DSTs.

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2. SCOPE

This Raytheon ATMSDI CTO-2 research plan outlines the steps that will be taken in FY02 to further the development of the DAG-TM concept. Because NASA Ames Research Center (ARC) and NASA Langley Research Center (LaRC) are using different approaches to concept development, each center will be addressed separately in this document as required.

The human factors subtasks described in this research plan define the work planned for FY02 based on stated research objectives collected from researchers at NASA ARC, NASA LaRC and the Raytheon team components. The research plan documents how we intend to accomplish the stated goals and outlines the plans of the NASA researchers at this time.

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3. SUBTASK 1: DISTRIBUTED DECISION MAKING

Task Lead: The Ohio State University, P. Smith

The goal of this subtask is to gain insights into how the NAS currently functions as a distributed system, and to explore ways in which a DAG-TM system should redesign and support such distributed work among flight crews, airline operations centers, traffic managers and controllers. For this fiscal year, emphasis will be placed on the integration of AOCs within alternative designs for such a DAG-TM system. Activities will include:

- Coordinate the addition of AOC and traffic flow management (TFM) elements to the current NASA Ames simulation, in conformance with the structure outlined in the DAG-TM documentation.
- Coordinate and fund the attendance of dispatchers at DAG research events.
- Work with NASA staff and AOC SMEs to develop a detailed scenario to study AOC roles within the DAG concept and to implement the capability to study performance within this scenario in a NASA simulation.
- Work with NASA staff and AOC SMEs to conduct this simulation — in those cases where materials and tools cannot be developed in FY02 to support full real-time AOC interactions, we will use pre-scripted behaviors to represent AOC interactions with the flight deck and ATSP.
- Document the scenarios, procedures, scripts, and storyboards emerging from DAG research activities in order to describe the state of the DAG concepts at the end of each fiscal year. This document will be provided as an appendix to the updated guidelines for FY02.
- Assist NASA to compare the outputs of the airborne and ATC DST conflict detection and resolution algorithms. Determine if there are differences in output, look-ahead effectiveness, etc., and analyze how this might affect DAG-TM operations in CEs 5, 6, and 11. The results of this assessment will be provided as a final report to NASA.
- Participate actively in DAG-TM planning meetings and simulations. Advise NASA on decision making and collaboration issues pertinent to DAG-TM and suggest appropriate strategies.
- Update the Subtask 1 literature review to include AOC involvement, weather and collaboration in DAG-TM.
- Update Subtask 1 Interim Guidelines document as necessary to reflect AOC involvement.

Comparison of Ground and Air-Side Conflict Detection and Resolution (CD&R) Tools (ARC) Move to subtask 1

To date, CD&R algorithms for flight deck applications and for ATSP applications have been developed independently. These current CD&R concepts have focused on the specific needs of the pilots and the ATSPs, which are unique in many respects. However, collaboration and coordination among the different users (pilots, ATSP, AOC) is a key element of the DAG-TM concept. Furthermore, because the roles and responsibilities will be shifted among the groups, it is necessary to ensure that CD&R information supports a common situational awareness and does not create confusion due to inconsistencies in alerting and resolution advisories. Therefore, FY02 research and evaluations will include investigations of how CD&R capabilities on the flight deck and for ATSPs must converge to reinforce team decision making and mitigate potential human performance degradation due to inconsistencies in the information. In addition, it is also necessary to evaluate user procedures to verify that the roles of all responsible parties are filled and that efforts are coordinated among groups. FY02 evaluations will focus on CD&R tools on the ground and in the air. This effort may be conducted either as part of a DAG-TM demonstration or as a stand-alone activity. The product of the effort will be a report documenting the results of the CD&R evaluations.

4. SUBTASK 2: HUMAN ERROR PREDICTION AND AMELIORATION

Task Lead: Titan, P. Kopardekar

The research effort will address human error modes, their potential, and error mitigation strategies under nominal and off-nominal scenarios for CE 5, CE 6, and CE 11. The Subtask 2 Interim Guidelines document will be updated to address how the error potential could be reduced and/or the impact (or severity) of errors can be minimized or eliminated. The Subtask 2 Interim Guidelines will also address specific error-tolerant design features, such as redundancy, integrated versus non-integrated information presentation, levels of automation, and graceful degradations.

The researchers developed a methodology to predict and analyze errors in FY01. The DAG-TM human error assessment methodology developed in FY01 will be finalized and applied to the current DAG-TM research concept. The focus is on identifying the human error potential or issues inherent in the DAG-TM procedures and DST user-interfaces in a variety of scenarios and procedures related to relevant DAG-TM CEs.

In conducting human error analyses, it is crucial to use representative scenarios. The range of ATM scenarios will include:

- Free maneuvering in en route operations,
- Trajectory negotiation under en route operations,
- Self-spacing under terminal operations,
- Transition between free maneuvering and controlled airspace under en route operations,
- Transition between en route and terminal operations,
- Mixed equipage operation, and
- Presence of critical situations such as severe weather, emergency, and system outages.

The researchers will examine external error modes, internal error modes, and psychological error mechanisms under the above scenarios for ATSP, FD, and AOC dispatchers.

The following approach will be used in predicting errors and identifying error mitigation strategies:

Step 1 – Conduct task analyses for each scenario for ATSP, FD, and AOC dispatchers,

Step 2 – Conduct cognitive walkthroughs to identify external error modes, internal error modes, cognitive domains, and psychological error mechanisms,

Step 3 – Compare the error potential of current operations and DAG-TM operations using Analytic Hierarchy Process (AHP) to ensure that the error potential (and severity) is reduced under proposed operations, Step 4 – Identify decision support tools and procedural characteristics using the Quality Function Deployment (QFD) process to ensure errors will either be eliminated or reduced by design features, and

Step 5 – Ensure that there are redundancies for critical tasks using a decision tree analysis.

The researchers will continue to collaborate and participate in FAA and Eurocontrol Action Plan 12. This effort includes reporting the results of the error analysis at NASA/FAA/ Eurocontrol Action Plan 12 meeting.

The researchers will also develop a simulation error data bank so that human-in-the-loop simulation errors will be recorded and lessons learned will be archived. The product of the Subtask 2 effort will be a report on the human error assessment results, including case studies demonstrating the use of error prediction methodology, identification of potential errors, and description of error mitigation strategies focusing on design and procedures.

Human Error Assessments of DAG TM Concepts and DSTs (ARC and LaRC)

An application of the research conducted as part of Subtask 2 will assess the error tolerance of a single concept element (CE 5) and current operations. The objective of this research is to develop prospective approaches and methods for evaluating error tolerance of alternative DAG-TM concepts and DSTs to complement the retrospective approaches used to date. This task will be an on-going activity for FY02 and will be conducted as new procedures, decision support tool features, and concepts are introduced at both ARC and LaRC. Results of the studies will be used to guide system designers in the development of error-tolerant systems for the pilot, ATSP, and AOCs.

5. SUBTASK 3: HUMAN FACTORS EVALUATIONS

Task Lead: Booz Allen, K. Helbing

The purpose of this subtask is to provide support to NASA's planned human factors evaluations of CE 5, CE 6, and CE 11. The objective of the human factors evaluations is to use a range of techniques to evaluate human performance and investigate human factors issues. Results from these evaluations will be used to validate the operational concepts and shape the research and development of DSTs and CEs.

A general description of FY02 Subtask 3 activities is provided below. Details related to specific planned human factors evaluations are in Sections 5.1 – 5.3.

- Support NASA ARC and NASA LaRC researchers in developing evaluation plans, experimental designs, data collection strategies, analysis approaches, and reports for FY02 DAG-TM evaluations. There will be one experiment at NASA ARC at the end of FY02. There will be TBD experiment(s) at NASA LaRC in FY02.
- Document the results of concept evaluations, issues, and future directions / next steps (i.e., what we did, what we learned, what's next) for the designated events at NASA ARC and NASA LaRC.
- Support design, conduct and analysis of part-task evaluations at both NASA ARC and NASA LaRC. Details on the part-task studies are provided in Section 5.3.
- Update Subtask 3 Interim Guidelines document as necessary to reflect AOC involvement.

5.1 AOC INVOLVEMENT IN DAG-TM CONCEPT

At NASA ARC, the concept element for trajectory negotiation (CE 6) among air- and ground-side stakeholders will be investigated in a human factors evaluation in September 2002. A major focus of this study will be the integration of the AOC into the negotiation process. As the DAG-TM concept matures, it is recommended that the following human factors issues be investigated in FY02 and beyond:

- The communication of preferences, constraints and clearances between air and ground,
- The coordination and exchange of information among the FD, AOC dispatchers and ATSPs,
- The technical issues that may arise with respect to common or uncommon conflict detection algorithms between the air and ground, and
- Operational transition issues.

5.2 CE 11: TERMINAL AREA SELF-SPACING

The Advanced Terminal Area Approach Spacing (ATAAS) study will employ high fidelity B-757 flight deck simulation capabilities at NASA LaRC, and be performed in conjunction with the Safe Flight 21 program. The objective is to evaluate the feasibility of the pilots' ability to maintain in-trail separation in the terminal environment with the use of CDTI decision support information and associated operational procedures. Evaluations will include measuring human performance, operational efficiency and safety.

On the NASA ARC CDTI, a "follow-me box" is currently proposed as a graphical representation of the time-based spacing interval. A study to be conducted at ARC in the first quarter of FY02 will assess this spacing tool.

In addition to the above evaluations, we will support NASA LaRC researchers with SafeFlight 21 Terminal Operations group. This support will include participation in relevant SafeFlight 21 meetings.

5.3 PART-TASK EVALUATIONS

Throughout FY02, several part-task studies will be conducted at ARC and LaRC in an attempt to resolve some open issues.

At LaRC, these evaluations will include:

- Vertical strategic resolutions,
- De-coupling speed and heading for lateral resolutions,
- Airspace hazard CD&R,
- Provisional resolutions (either a menu or 'rubber-banding'), and
- Pilot selectable CD&R buffers.

6. SUBTASK 4: HUMAN FACTORS METRICS

Task Lead: Titan, N. Sacco

In FY01, the researchers developed a database of human factors metrics that apply to DAG-TM research and developed initial guidelines for metrics use. The focus of the work is now shifting from researching the metrics to applying these metrics in the DAG-TM research environment.

In FY02, the researchers will conduct the following activities:

- Update the metrics database as necessary,
- Develop an analysis section for each metric,
- Identify technical, system, and equipment requirements for collecting metrics at NASA facilities and laboratories,
- Identify metrics for collaborative decision making, trust in automation and other system users, and for AOC dispatcher operations,
- Investigate possible metrics for determination of concept feasibility,
- Convert the database into a CD-ROM with search and query options for metrics, analysis methods, collection requirements, and lessons learned,
- Continue to provide briefings and consultation to NASA and FAA's CTAS team to support the DST development effort,
- Provide technical support to NASA research staff to set up the required data collection techniques for obtaining qualitative and quantitative human performance measures,;
- Support the design of experiments activities for NASA ARC and LaRC studies, and
- Update Subtask 4 Interim Guidelines document as necessary to reflect metrics for AOC involvement.

The researchers will also closely tie the metrics to NASA's Technology Readiness Levels (TRLs) to ensure that these metrics address TRL requirements.

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7. SUBTASK 5: SIMULATION REQUIREMENTS

Task Lead: Titan

In FY01, researchers identified simulation facilities and laboratories at the NASA ARC, NASA LaRC, The researchers also examined the role and use of fast-time simulations and modeling for preliminary examination of CE operations.

In FY02, the researchers will conduct the following activities:

- Update the literature review and guidelines to include use of appropriate AOC simulators (including development and/or reuse of existing simulator),
- Update the literature review and guidelines to identify the necessary weather information for ATC displays,
- Develop requirements and guidelines for the incorporation (technical requirements as well as display characteristics) of real-time, forecast and simulated weather (for the FD and ATSPs) for conducting demonstrations and experiments, and
- Assist NASA ARC and NASA LaRC in the development of AOC, weather and terrain, and other capabilities required for examining CE benefits and feasibility.

The researchers will also develop a database of operational scenarios to be used for demonstrations and simulations. This database will include lessons learned so that the simulation capability may be continuously upgraded to address fidelity requirements.

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8. SUBTASK 6: FLIGHT DECK GUIDELINES

Task Lead: Booz Allen, R. Adams (LaRC), K. Helbing (ARC)

The goal of the following tasks is to provide researchers with the knowledge to apply human factors principles to FD development in the DAG-TM environment.

- Update Subtask 6 Literature Review to address the inclusion of weather information and DSTs on the FD,
- Increase collaboration and support for NASA ARC CDTI research activities,
- Supervise, provide human factors inputs to the design and preparation of a CDTI interactive prototype (animated specification) to demonstrate baseline concepts,
- Create a NASA "Baseline Human Factors Design Approach Document (HFDAD)" for CDTI designs that addresses CE 5, 6 and 11 operational needs. This document will discuss the basis and rationale for the NASA ARC and NASA LaRC design approaches, and the information needs and requirements that the display features and functions support, and
- Update the CDTI Guidelines document to include information relevant to weather information and decision support, collaboration between the FD and other stakeholders, and other developments that surface as the concept evolves in FY02.

A review of literature pertaining to the display of weather, as it relates to pilots and ATSPs, will be conducted. Research on existing weather displays will address issues such as: what weather displays/information sources currently exist for pilots and ATSPs; what kind of weather is depicted (or, what is NOT depicted that is necessary); how the information is presented; any human factors studies that have been conducted on display acceptability/usability for these existing displays. In addition, literature pertaining to research programs related to the display of weather in the context of FD and ATSP tasks in DAG-TM will be reviewed.

As part of the development process, interactive prototypes CDTIs will be developed. These prototypes will be used to demonstrate display and interface concepts discussed in the Baseline NASA LaRC and NASA ARC CDTI documents. We will provide guidance to the prototype developer with respect to the functionality and features of the baseline CDTIs for ARC and LaRC.

The HFDAD will present the FY02 CDTIs that are implemented at NASA ARC and NASA LaRC. Because the display designs have diverged significantly, the two display formats will be presented separately. Feature descriptions will be provided along with the human factors rationale on which the features are based.

For FY02, the major focus of the CDTI Guidelines update will be on the inclusion of weather information and DSTs guidelines and the addition of any display features necessary to enable trajectory negotiation among the stakeholders. Changes to existing guidelines will be made to reflect lessons learned from FY01 research results and provide information from ongoing literature reviews.

Lastly, Booz Allen will assist Walt Johnson in the identification of host sites for a distributed CDTI simulation. Currently, Booz Allen, Georgia Tech, Raytheon, and San Jose State University are proposed sites. Booz Allen is coordinating this effort with George Lawton with respect to system requirements.

9. SUBTASK 7: TECHNICAL MANAGEMENT AND SUBTASK INTEGRATION

The following technical management tasks will be completed in FY02:

- Technical coordination and management across subtasks,
- Support Quarterly Program Reviews,
- Prepare Annual Progress Report (CTOD 6),
- Promote / educate aviation research community and industry on the application of DAG-TM Guidelines (all subtasks), and
- Plan a DAG compendium document, develop the outline in FY02. This will be a reference for the concepts, procedures, displays, and experimental results from the overall Ames DAG research efforts. Incorporate documents from other sources and create content as needed to provide a full and complete description of the results of the entire DAG research effort.

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10. FY02 SCHEDULE & MILESTONES

Activity	Completion Date
Deliverables	
Initial Human Factors Assessment of CE 6 (CTOD 10)	December 31, 2001
Final Report – NASA ARC Concept Demonstration	December 31, 2001
Updated Research Plans (CTOD1)	March 11, 2002
Update Subtask Literature Reviews (CTOD 2)	
Combined Subtask 1, 5, 6 Weather Literature Review	June 3, 2002
Updated Subtask Interim Guidelines Document (CTOD 4)	
Subtask 1	Sept. 24, 2002
---- Document describing state of DAG concepts	Sept. 24, 2002
Subtask 2	Sept. 24, 2002
Subtask 3	Sept. 24, 2002
Subtask 4	Sept. 24, 2002
Subtask 5	Sept. 24, 2002
Subtask 6*	June 28, 2002
Baseline CDTI Documentation (NASA ARC and LaRC)	May 10, 2002
Human Error Assessment Report	July 22, 2002
NASA ARC DAG Test Plan	August 30, 2002
CD&R Report	September 16, 2002
Activities	
NASA LaRC – conduct study to assess spacing tool	January 2002
NASA ARC Simulation	June 2002
Conduct AOC focus group, develop and document AOC-oriented scenarios	March 31, 2002
ARC – conduct study to assess CD&R tools	Q2 2002
Conduct AOC focus group, develop and document AOC-oriented scenarios	June 30, 2002
Develop Test Plan for DAG Study at Ames	Aug. 29, 2002
Conduct AOC focus group, develop and document AOC-oriented scenarios	September 30, 2002
Support NASA ARC DAG Study	September 2002

* AATT Milestone

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11. RAYTHEON TEAM RESOURCES

To ensure proper representation of each of the stakeholders, leads will be assigned to represent each of the stakeholder's interests. Ms. Katrin Helbing and Mr. Richard Adams will lead the FD research – Ms. Helbing will be primarily focused on NASA ARC evaluation activities, while Mr. Adams, who is on-site at NASA LaRC, will be primarily focused on NASA LaRC evaluation activities. Mr. Adams will support LaRC on a full-time basis. Dr. Parimal Kopardekar will lead the ATSP research, and Dr. Phil Smith will lead the efforts related to AOC dispatchers. Dr. Jacqueline Duley, Mr. Paul Mafera, Ms. Nicole Sacco, and Mr. Brian Legan will support research at Ames. The other researchers will provide additional support on an as-needed basis (e.g., during evaluations).

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